THE PHOENIX MISSION TO MARS. P. H. Smith[1] and the Phoenix science team, [1]Lunar & Planetary Lab, University of Arizona, 1629 E. University Ave, Tucson, AZ 85721, psmith@lpl.arizona.edu.

Introduction: The Phoenix mission was selected in August 2003 as the first Scout mission to Mars. The ground rules for this Scout opportunity require missions to launch in 2007 and meet a cost cap of $325M in fiscal year 2003 dollars that encompasses all mission costs including the launch vehicle, an education program, and a healthy reserve. Scouts are principal investigator (PI) led missions like those of the Discovery program; Peter Smith is the PI for the Phoenix mission. Barry Goldstein has been designated the project manager at JPL and Lockheed Martin has the contract to build, integrate, and test the spacecraft.

Phoenix derives its name from the mythological bird that is reborn from the embers of its former incarnation. Appropriately, the Phoenix spacecraft is the Mars Surveyor 2001 (MSP) spacecraft that resides in the Lockheed Martin highbay in Denver. It was placed in storage after cancellation in 2000 following the loss of Mars Polar Lander (MPL). The payload derives heritage from the MPL and MSP developments, but has been optimized and tailored to its new mission: studying the history of water contained in the near surface ice recently discovered in the northern plains.

Activities during phase B have concentrated on identifying safe landing sites, deriving requirements, and preparing for testing of the propulsion system. The spacecraft will launch on a Delta 2 in August 2007 and land on Mars in June 2008. The digging phase of the mission will last 3 months and then continue as a weather station until the Sun can no longer power the spacecraft. The total duration of the mission is expected to be 150 sols.

The science goals (described below) will be met in 3 ways. Imaging of the scene will serve to provide context of the landing site and the geomorphology of the periglacial terrain will help in the assessment of the processes that shape the northern polar plains. The robotic arm will dig beneath the surface into the unexplored subsurface of Mars and provide samples for chemical analysis. Two instruments are specially designed to examine the mineralogy and chemistry of these samples as well as a microscopic examination of the grains. Finally, a capable weather station will monitor the temperature and pressure of the landing site. A lidar will examine the distribution of aerosols in the boundary layer and the panoramic camera has the ability to track the column abundance of dust and ice.

As a consequence of studying the history of water in the northern plains, Phoenix will take the first steps in answering the complex question of whether the subsurface ice represents a biologically habitable zone. If the ice can melt when the orbital dynamics modify the Martian weather and climate, then perhaps microbes could survive the 50,000-year "winter" to thrive during the short warm season. Phoenix will test the samples for organic molecules and look for mineral and chemical evidence that the ice periodically melts.

Science Objectives: The Odyssey Gamma Ray Spectrometer (GRS) team announced in Spring 2002 the discovery of large amounts of water ice poleward of 60 degrees latitude within a few 10s of centimeters of the surface [1,2]. Mellon and Jakosky [3] and other scientists had predicted for some time that ice would be stable near the surface in balance with water vapor diffusion through an overburden of regolith. The actual measurement of ice with 3 independent instruments allowed the GRS team to estimate the depth and abundance of ice with a simple two-layer model. The amount of ice is on the border of being too large for vapor diffusion appearing more like a dirty-ice layer than icy dirt.

Of all the accessible sources of water on Mars this near surface icy layer seems to us to represent the greatest potential for a habitable zone. Recent work has verified our hopes [4] that periodically, through variations in obliquity and precession of the polar axis, the temperature of the ice-soil boundary exceeds –20 C and melting can occur. Granted the melting may only produce a monolayer of water on crystalline surfaces, but this is enough to allow mobility and maintenance in biologic communities on Earth. Higher temperatures will allow reproduction and growth.

Phoenix will land in the northern near-polar region and dig through the regolith searching for the ice-soil boundary [5]. Instruments on the deck will receive samples and analyze the chemistry, the volatile inventory, the grain morphology, and the biologic potential of this zone. Although there are no "life-detection" instruments on board, we suspect that a longterm active biological community will leave observable signatures in the soil horizons and chemical tracers in the ice.

Even if the ice layer cannot by reached at our landing site, Phoenix will become the first scientific station in the polar regions to return useful data. Not only will the soil be trenched and surface features examined for evidence of a freeze-thaw cycle, but the weather throughout the polar summer and fall will be monitored. Temperature and pressure will be measured on an hourly basis. A lidar will make measurements of the boundary layer for the first time to be compared with mesoscale models that are now becoming an important tool in predicting near-surface weather.

Images created by data from our cameras will allow visualization of the site in an unprecedented manner. During descent a wide-field camera will produce a set of nested images surrounding the landing site. After landing, these will be compared to panoramic images so that the exact distances to features of interest can be computed; the ultimate products is the distribution of the sizes and shapes of features in the scene. The panoramic camera is also stereoscopic and multi-spectral throughout the sensitive range of the CCD detector; its resolution is equivalent to the human eye, about 0.25 mrad/pixel.

A camera on the robotic arm that digs the trench starts to reduce the scale at which we examine the scene; closeup images of the trench walls will provide insight into the layered structure and grain size of the soil. Samples will be provided to an optical microscope housed on the deck that images the tiny grains to 4 microns/pixel. Finally, an atomic force microscope has been developed in Switzerland to enlarge our view of selected objects on the microscope stage (resolution at the 10 nm scale).

To summarize, our goals are to understand the near surface chemistry and geology of a polar landing site. We will examine the ice-soil boundary for periodic melting and biologic potential, our goal is to detect an accumulation of organic molecules. The hazards to life that exist in the ice layer, particularly salts and oxidants, will be quantified. Finally, we will characterize the polar weather throughout northern summer and fall with particular attention to the distribution of water in all its phases.

Implementation. Phoenix will modify the 2001 lander according to the recommendation of the Young commission [6] and the Casani JPL review board [7]. The lander has been stored for 4 years at the Lockheed Martin facility in Denver; they will be responsible for refurbishment and improvements along the lines of the review boards. Guided entry and full communications during entry and descent will reduce the risks to an acceptable level. Communications will include UHF relay to orbiting assets (MGS, Odyssey, and MRO) and a high gain antenna for a direct-to-Earth link.

Many of our instruments are already delivered. The descent imager (MARDI) and the robotic arm with its camera are in bonded stores at JPL, and so is the MECA instrument with its wet chemistry cells and microscopes. However, the chemistry cells have shelf life issues and the cells will be rebuilt. Other instruments are build-to-print from the MPL: the panoramic camera (SSI), and TEGA. New instruments include the MET station with its lidar that will be provided by our Canadian partners and a mass spectrometer that replaces the tunable diode laser for the evolved gas analysis instrument on TEGA.

Mission scenario: After a launch in August 2007, Phoenix will land in late May 2008 at Ls=87 (late Spring). The engineering data acquired during descent and the descent images plus the first panoramic images will be returned immediately. A successful landing will give the Mars program a choice of landing vehicles for future missions; airbags are not for everybody. The first week will be reserved for examination of the landing site with the remote sensing cameras and calibration of the instruments.

The digging phase (first 90 sols). After surface samples are collected and verified, trench digging begins. The sampling strategy requires surface samples, samples from within the dry regolith and samples from the ice-soil boundary. If the robotic arm is capable of digging into the icy soil, another sample will be collected from within the ice. To be sure of getting an ice sample, ripper tines and scrappers are added to the back of the scoop. The digging and sampling activities have been grouped into 8-sol cycles that include 4 days of digging and monitoring the trench and 4 days of examining samples with TEGA and MECA. Seven of these cycles are baselined with adequate reserve added in case digging is more difficult than planned.

Polar climate phase. As the season turns to fall and winter, Phoenix will continue to operate until the Sun is too low on the horizon to charge the batteries. This is period when power must be conserved. The cameras will will be programmed to look for the first carbon dioxide frost deposits as the seasonal cap approaches. The MET instruments will record the decrease in temperature and pressure as fall turns to winter. We do not expect that the lander will survive the winter and have no plans for its recovery in the spring.

References: [1] Boynton, W. V. *et al*. (2002) *Science*, *297*, 81. [2] Feldman, W. C. *et al.* (2002) *Science, 297*, 75-78. [3] Mellon, M. T. and Jakosky, B. M. (1993) *JGR, 98,* 3345-3364. [4] Jakosky, B. M. et al. (2002) Astrobiology. [5] Mellon, M. T. *et al.* (2004) *LPSC XXXV*. [6] Young, T. *et al*. (2000) “Mars program independent assessment team (MPRIAT) summary report.” [7] Casani, J. *et al.* (2000) “Report on the loss of the MPL and DS-2 missions.”